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INFLUENCE OF SURFACE COATINGS ON EXO-ELECTRON
EMISSION DURING FATIGUE

QUARTERLY PROGRESS REPORT NO. 7
1 March - 1 June 1963

Task Order Contract No. NASr-63(02)

M.R.I. Project No. 2553-P

For

Office of Grants and Research Contracts
Code SC
National Aeronautics and Space Administration
Washington 25, D. C.



MIDWEST RESEARCH INSTITUTE

M I D W E S T R E S E A R C H I N S T I T U T E

INFLUENCE OF SURFACE COATINGS ON EXO-ELECTRON
EMISSION DURING FATIGUE

by

J. C. Grosskreutz
David Benson

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PREFACE

This report covers the research performed during the period 1 March - 1 June 1963 under Contract No. NASr-63(02), M.R.I. Project No. 2553-P. The research was directed by Dr. J. C. Grosskreutz and is under the supervision of Dr. Sheldon L. Levy, Director, Mathematics and Physics Division. Mr. David Benson carried out much of the experimental work reported here.

Approved for:

MIDWEST RESEARCH INSTITUTE



Sheldon L. Levy, Director
Mathematics and Physics Division

10 June 1963

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I. EXPERIMENTAL WORK

A. Direct Detection of Exo-electrons During Fatigue

Shortly after the beginning of the current quarter, the DuMont electron multiplier tube with which we have been working suffered a marked deterioration in over-all gain. It was not possible to restore the tube to its original characteristics by the usual device of high vacuum bakeout. Apparently, prolonged exposure of the dynode surfaces to oil diffusion pump vapors and repeated atmospheric exposure caused an irreversible deterioration of these surfaces. Similar difficulties have been reported by workers at the United States Steel Laboratories (see Section II).

It was therefore decided to obtain a replacement electron multiplier whose dynode surfaces would not be sensitive to atmosphere or pump vapors. We have purchased an electron multiplier structure (ITT, FW-141) which is ruggedized and contains integral voltage dividing resistors. The entire structure is bakeable and is unharmed by exposure to atmosphere. It does, however, require a vacuum of 10^{-5} Torr or better in order to operate reliably. The fatigue testing chamber was therefore modified in order to obtain the required vacuum for this multiplier. A vac-ion getter pump now replaces the vapor and rotary pumps; the new system also avoids the difficulties of pump oil contamination. The system is still limited, however, to a pressure of about 2×10^{-5} Torr which is the vapor pressure of the rubber O-rings used in the system. Low vapor pressure O-rings of du Pont "Viton" have been ordered.

Because of these difficulties and limitations, no further attempts have been made during this quarter to reproduce the measurements of exo-electron emission from cyclically stressed aluminum described in the last Quarterly Progress Report.

B. Effect of Environment and Surface Films on Exo-electron Emission From Strained Aluminum

The difficult job of fabricating the ultra-high vacuum sample chamber and manipulator described in the last Quarterly Report was accomplished by Varian Associates. A vacuum of 2×10^{-8} Torr was obtained following a 48-hr. bakeout. Longer bakeouts will be required for lower pressures. The new ITT electron multiplier structure has been mounted facing a polished 99.99 per cent aluminum specimen, and the change in multiplier current observed during tensile strain of the sample. Although straining was continued until fracture, we observed no exo-electron emission at either 10^{-8} or 10^{-5} Torr. In order to further enhance the emission, we admitted light to the chamber but this did not improve the signal-to-noise ratio.

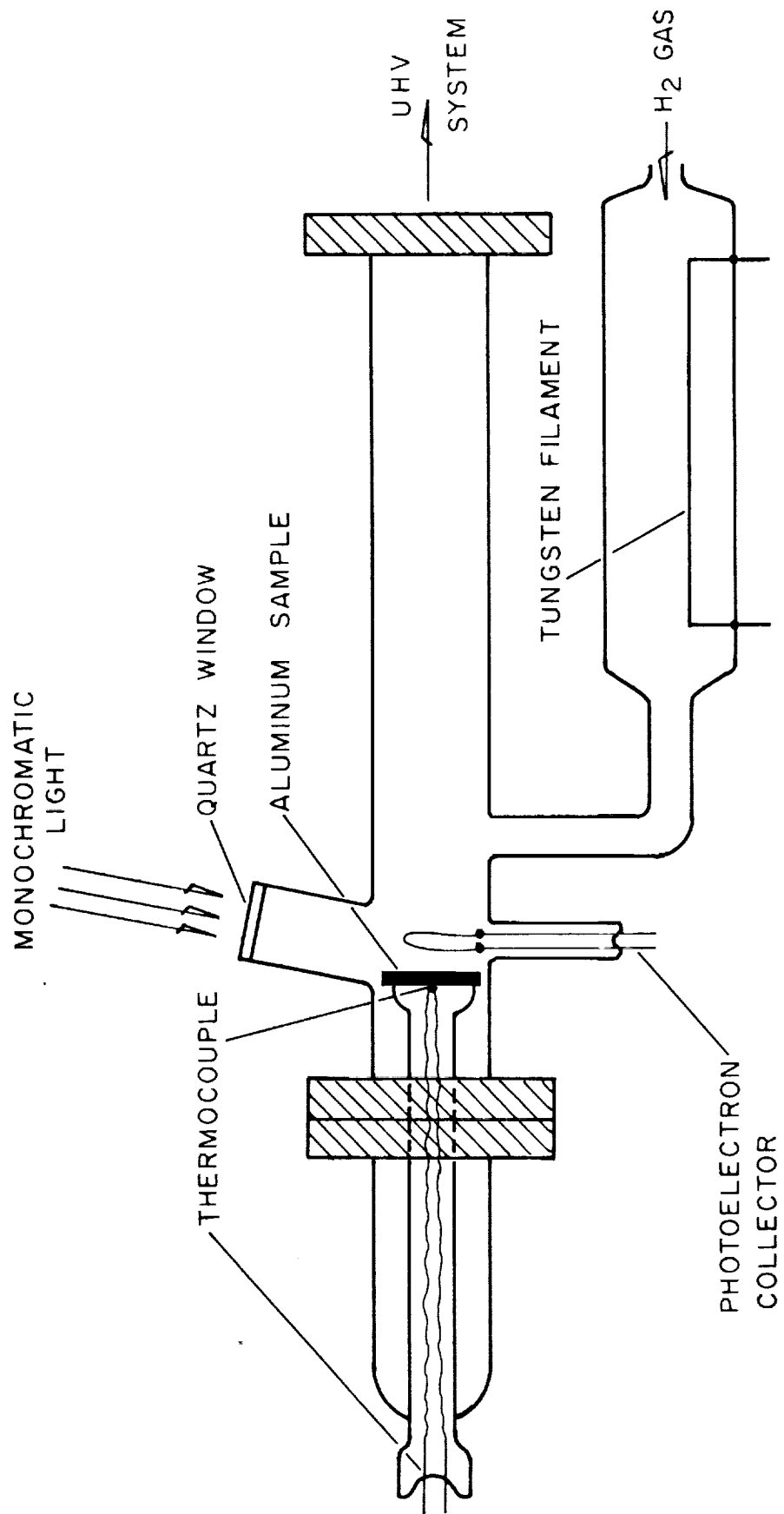
These negative results prompted us to measure the gain of the new multiplier tube in its operating environment. Using a thermionic source of electrons (the ITT structure is insensitive to light), we have determined that with an interstage potential of 125 v. the over-all gain is 3,000. This gain is too small to allow us to distinguish the weak exo-electron emission from the dark current, which is of the order of 2×10^{-10} amps. It appears necessary to increase the high voltage applied to the tube, a step which is beyond the scope of the power supply presently in use.

Although our new electron multiplier can be calibrated with a thermionic source, we have completed the construction of several electron emitting diodes which were begun during the previous quarter's work. Several of these diodes have been fabricated and tested. Currents as high as 10^{-6} amps are emitted. However, the emission is rather erratic above 10^{-10} amps. This in no way limits the usefulness of the diode as a calibration electron source. Whether the emission at the low currents is sufficiently reproducible to give quantitative calibration of the multiplier has not yet been determined.

Experiments designed to strip completely the oxide coating from aluminum were described in the last Progress Report. The objective of this study is to determine the exo-electron emitting characteristics of aluminum with various thicknesses of oxide coating, including zero thickness. During this past quarter, apparatus was designed and constructed to carry out the investigation of the efficiency of atomic hydrogen in stripping the oxide layer. The apparatus is shown schematically in Fig. 1. Hydrogen is admitted to the system and dissociated into atomic hydrogen by passing over the hot filament shown in the side arm of the tube. A thermocouple monitors the temperature of the thermally isolated sample. In theory, as oxide is removed and clean aluminum surface is exposed to the hydrogen, the recombination rate at the surface, and hence the temperature, should rise. Further monitoring of the oxide removal will be carried out by a measurement of the photoelectric threshold. Monochromatic light will be emitted through the quartz window striking obliquely the surface of the cleaned aluminum. Photoelectrons will be collected by the circular filament immediately in front of the sample. The entire sample chamber attaches to our ultrahigh vacuum system and should attain a vacuum of 10^{-8} - 10^{-10} with proper bakeout.

II. DISCUSSION AND PLANS FOR FUTURE WORK

The experimental work on detection of exo-electrons during this past quarter was fraught with difficulties centering about reliable electron multiplier operations. On a recent trip to the East Coast, one of us (JCG) talked over this problem at length with Messrs. M. A. Conrad and S. Levy at the United States Steel Laboratories, Monroeville, Pennsylvania.



SCALE: 1" = 1/2"

Fig. 1 - Schematic Diagram of Apparatus for Stripping
Oxide Layer from Aluminum

These two men have been investigating exo-electron emission from fracture surfaces of aluminum, nickel and various steels. The majority of their work has been carried out using a Geiger counter for detection of the exo-electrons, mainly because of the difficulties of reliable reproduction of data using an electron multiplier. It appears that the difficulties which we have encountered with these tubes are quite common to the detection of low energy, low intensity electrons. Although Conrad and Levy have at present abandoned the use of electron multipliers in this context, they both felt that for a precise investigation of the sources of these electrons, electron multiplier detection was mandatory. The main reason for this condition is that the use of Geiger counters requires that the sample remain in the gaseous atmosphere which fills the Geiger tube. The investigation of oxidation rates in different atmospheres and temperatures cannot be made with such a detector. Because of the nature of our investigation, we feel strongly that we should continue to adapt the electron multiplier to the successful and reproducible detection of exo-electrons.

By virtue of the talk with Conrad and Levy, we have been able to advance an hypothesis regarding the mechanism of exo-electron emission from strained aluminum. The work at U. S. Steel showed that exo-electrons from fracture surfaces of aluminum could only be detected in a Geiger Counter if the surface of the sample were weakly illuminated with light. Thus, Conrad and Levy concluded that the entire effect was simply enhanced photoelectric emission. The fact, however, that we have been able to observe exo-electrons during fatigue in total darkness indicates that at least for part of the emission light is not necessary. These two observations can be reconciled when it is remembered that the exo-emission which we have observed in the dark from fatiguing metals dies away promptly following fracture of the samples. The exo-electrons detected by Conrad and Levy, on the other hand, continued to be emitted for many hours following the fracture, provided light was incident on the surface. Moreover, the transfer of their fractured sample into the Geiger tube and establishment of gas flow through the tube required approximately 1 min. before first observations could be made. Therefore, we propose that exo-electrons are emitted in two ways. First, "prompt" exo-electrons are emitted at the moment new surface is produced either by slip or by fracture and the energy for release is supplied by oxidation of this new surface. These electrons would not be emitted in an oxygen-free environment. The second class of electrons, which we shall call "delayed" exo-electrons, can be stimulated and emitted by illuminating the new surface with visible light. This means that the work function of the aluminum has somehow been reduced by the plastic deformation since photoelectrons are not normally observed under visible light. Most probably, excited electron states are produced near the surface and are gradually emptied over a rather long period under the action of visible light.

During the coming quarter, every effort will be made to obtain a workable electron multiplier for the detection of exo-electrons. We shall try increasing the voltage per stage, cooling the tube to improve signal-to-noise ratio, and possibly the use of other brands of electron multipliers. Once this difficulty is overcome, the apparatus is ready and waiting to proceed with the measurement of the emission of exo-electrons during fatigue and the effect of surface films on this emission. The experiments to strip oxide film from aluminum will begin immediately during the next quarter and results should be available for the next Quarterly Report.